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ABSTRACT

This chapter presents the theory and research underlying Merrill's concept of learner control as an instructional system. Three levels of learner control--content-control, display-control, and control of conscious-cognitive processing--and efforts to manipulate these variables are described, and a model of external and internal learner control is presented. Different types of individualized instructional systems are compared on the basis of the learner control involved, and adaptive instructional models are considered. Findings of learner control research are examined in an effort to determine the level of learner control that will maximize student performance. It is argued that all instruction involves some level of learner control, and the challenge is not whether or not learner control should be made available, but how to maximize the student's ability to use the learner control available. Four figures and one table are provided. (46 references) (Author/EW)

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Chapter 17

What Is Learner Control?

M. David Merrill

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Many of the current aspects of educational technology which are of general interest involve situations in which the assumption that all students should receive identical mediations of instruction is either untenable or unsupported. Examples of such situations include self-instruction, computer-assisted and computer-managed instruction, individualized instruction, and programmed instruction.

Much research has been conducted involving variables affecting such situations, and has been published under such headings as ATI, cognitive style, individual differences, and self-paced instruction. All of these topics involve arranging the choices among the various mediational tracts for the student, unsually based upon some pre-measured student characteristic.

But what happens if the choice among the various possiblities is left up to the student?

This chapter examines several aspects of this situation, using the concepts of student-controlled instruction and display selection. A model for display processing is developed, and relevant research is reviewed.

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WHAT IS LEARNER CONTROL?

One of the problems which has plagued educational research is the ambiguity of the terms which are used to describe instructional phenomena. **Learner control** describes some rather specific instructional conditions, yet there is sufficient ambiguity in meaning that differrent investigators using the term frequently refer to different instructional events. The first section of this chapter is an attempt to clarify the several meanings which the term **learner control** can assume.

Types of Learner Control

Content Control. The earliest use of the term **learner control** referred to the opportunity for a student to make content selection. However, even in this context there is sometimes confusion as to the extent of the learner's choice. It is standard practice from junior high school through university to allow students increased choices in choosing the classes in which they enroll. At the junior high level a student usually has a choice among two or three alternatives in addition to required courses of study. At the high school level a student often has the opportunity to select as many as half of the courses in which s/he enrolls. At the university the choice is almost unlimited, since the student can first select the particular university, subject to admittance requirements, and once admitted can select from a wide variety of curricula, and often, depending upon the area of specialization, can also select from a considerable number of elective courses. While the term

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learner control connotes this curriculum choice, the use of the term in this context is rare. Curriculum choice in this broad sense is usually not what is meant by **learner control.**

The first introduction of the term learner control (Mayer and McCann, 1961; Mayer and Clark, 1963) referred to the opportunity for a student to sequence the objectives within a particular course of instruction in any order that the student desired. In these studies the instruction assumed a form of Socratic dialogue in which the student could inquire from a subject-matter expert concerning those aspects of the topic which the student felt s/he wanted to explore next. These studies showed that allowing students **sequence control** over the objectives of a course shortened study time significantly with no apparent loss in comprehension.

Control of Pace. Pacing, the opportunity to study a given unit or lesson as long as needed, is another educational variable which is connoted by the term **learner control.** However, as with curriculum selection, pacing has more frequently been referenced by other names such as individualized instruction, self-paced instruction, or dindividually progressed instruction rather than by the term **learner control.**

Display (Strategy) Control. Our own work has included content control and self-pacing but has also introduced and emphasized display or strategy control. (Merrill, 1973; Merrill, 1975; Merrill, note 3; Merrill, note 4; Merrill and Axtell, note 5; Merrill, note 6; Merrill, Schneider, and Fletcher, 1980.) An instructional display is a presentation of a single subject-matter idea. A display can consist of a general statement, such as a definition, a set of steps in a procedure, or a cause-and-effect proposition; or a display can consist of a specific example, such as a representation of a particular object or event, a demonstration of a procedure, or an illustration of some cause-and-effect phenomena.

The display is not equivalent to the physical form of its display. A novel, for example, may be a single display if the subject-matter idea is the plot of the novel; it may be a single page of the novel if the subject-matter idea is the illustration of typical sentence structures characteristic of the novel's author. If the concept consists of the definition of a particular species of tree, the display may be a photograph of the shape of a leaf or the tree (if the species is defined in terms of shape), or a series of photographs of the flower, of the seed and of the leaf-shape (if the species is defined in terms of a composite of these things). The display is always determined by the subject-matter idea, never by the physical form of presentation of that idea.

Display control is based on the assumption that an instructional sequence can be divided into a series of individual displays and that these displays can be categorized into a limited set of types each with unique characteristics. Display control exists when a student is provided a mechanism for selecting and sequencing those displays which s/he feels are required to understand a given objective. At least three types of display control are involved: selecting of the number of displays required for perceived mastery; control of the sequence of different types of displays; and selection of various displays elaborated to include information designed to facilitate the student's comprehension of the material presented.

Control of Internal Processsing. As implemented by most investigations, learner control has been limited to the learner's selection and sequencing of external stimulus material. Content control is the selection and sequencing of externally stated objectives; display control is the selection and sequencing of externally presented displays. Self-pacing implies that a student may take longer to process a given presentation than another student but the investigations in this area have also limited their concern to the manipulation of events external to the learner.

The term **learner control** also connotes the ability of the student to select and use a variety of internal processing strategies as s/he interacts with the presentations which comprise the instruction. Effective and efficient performance is a result of the interaction of these internal processes with the stimulus materials which have been selected for, or by, the student. It is likely that even in situations in which the presentations are selected for, sequenced for, and paced for the student, that s/he can still exercise a considerable amount of learner control. Those students who have developed effective internal processing strategies may be able to compensate for a wide amount of variance in the instructional displays presented to them; those students who have less effective internal processing strategies may be more subject to performance decrements as a result of inadequate presentations. Internal control of cognitive processing may enable students to perform much more adequately than would be expected and probably accounts for the limited effect that the manipulation of stimulus materials seems to have in many instructional situations.

Manipulation of Learner Control

Content Control. Previous investigations have provided content control by making available an array of content choices (segments, lessons, units) which the student can order in any way s/he wishes or, in some cases, which the student can skip should s/he feel that the material in a given component is already sufficiently understood. This type of control is hindered when the segments, lessons and/or units of instruction are sequenced for the student. Linear delivery systems such as lectures, videotape, tape/slide presentations, or movies make the reordering of content components difficult, assuring that most students will study them in the order given. Students can still elect to skip some components merely by "turning off" during a given presentation. This is easier in

expository presentations than in presentations which require active student participation or responding.

Workbooks, textbooks, and other materials which are manipulated by the learner in a self-paced individualized-study mode enable him/her to exercise some degree of content control. Most students probably take the path of least resistance, however, assuming the teacher knows best and following the prescribed content sequence.

Display Control. Formal provision for display control is of relatively recent origin and has not been widely investigated. Our own work with the TICCIT system (Merrill, Schneider, and Fletcher, 1980) provided for display selection and sequence control by means of rule, example, and practice buttons. In most instructional materials individual displays are often embedded in the instructional materials in such a way that their identification and isolation is difficult. Hence, the manipulation of primary-presentation display and sequence is not likely to occur in most instructional situations. However, recent workbooks, texts, tape/slides, and other individual study materials have begun to isolate primary-presentation displays, facilitating the student's ability to utilize those displays which s/he feels are needed and to skip those which s/he perceives to be unnecessary.

Conscious Cognition. Most learner control and other individualized instructional situations have not attempted to either monitor or manipulate the student's conscious cognitive activities. It is apparent that in this realm student choice is relatively independent of the delivery system. S/he can choose to use whatever mental processing seems to be appropriate for learning a given display whether that display is selected by the student or presented to the student by the instructional system. By the appropriate selection of cognitive processing activities a student may be able to compensate for a less-than-adequate display or display sequence. It may also be likely that many students do not use optimal processing in instructional situations. While it is difficult to constrain cognitive activities the student could be taught more appropriate processing and encouraged to use these strategies where appropriate.

Meta-cognition. Most individualized learning situations have involved adaptive models which are external to the learner. We often naively assume the student is following the prescribed model. But in addition to subject matter, students also acquire some internal theory about how to learn. This internal strategy is often ignored in investigations of learner control or individualized instruction. While direct control of a student's "how to learn" model is not likely to become possible, it is possible that students could be taught to use more appropriate adaptive models which would improve their performance.

EXTERNAL AND INTERNAL LEARNER CONTROL: A MODEL

We have recently completed a series of studies investigating the effect of learner control over presentation displays within a given lesson (NSF Project SED-76-01650; see the final section of this chapter for a summary of our findings). To some extent our findings were disappointing in that we did not find universal group differences favoring learner control of display selection and sequence. However, one observation was very striking. When students are given control over what display to study next, they use a wide variety of strategies, exhibit considerable differences in the number of displays used, in the sequence of these displays, and in the latency on the various types of displays. Even more striking, however, is that extensive correlation analysis between these various display selection variables and performance does not show any systematic relationships. For example, one student may use 20 displays to learn a lesson while another student may use 100, yet their performance is not significantly different. We also found that these divergent patterns of display selection do not correlate with typical measures of aptitudes such as GPA or ACT scores. This type of finding suggested to us that we could no longer ignore the cognitive activities of the student. It must be, because equally capable students seem to learn equally well from considerably different configurations of instructional displays, that what they do in order to cognitively process the information presented must differ as well.

It is postulated that there are four levels of conscious processing over which the learner can exercise deliberate learner control: content selection, display selection, conscious cognition, and meta-cognition. Content selection refers to a decision on the part of the learner about what objective (segment, lesson or unit) to study next. Display selection refers to a decision on the part of the larner about what type of presentation s/he wishes to study next. Conscious cognition refers to the mental processes the student uses to encode the information presented by a given display. Meta-cognition refers to the "how to study" model which the student uses to guide her/his interaction with the instructional system being used.

Figure 17-1 is a diagrammatic representation of these levels of processing. This diagram represents a maximum learner control system, such as the TICCIT system, for which the learner has both content and display control. Content selection, display selection, conscious cognition, and meta-cognition are all shown as rectangular boxes representing functions which are internal to the learner. Functions on the "external function" side of the diagram include the content array, the display array, and the adaptive instructional model which controls these presentations. Trapezoids represent potential outputs from the learner. The most typical is response latency or correctness-of-

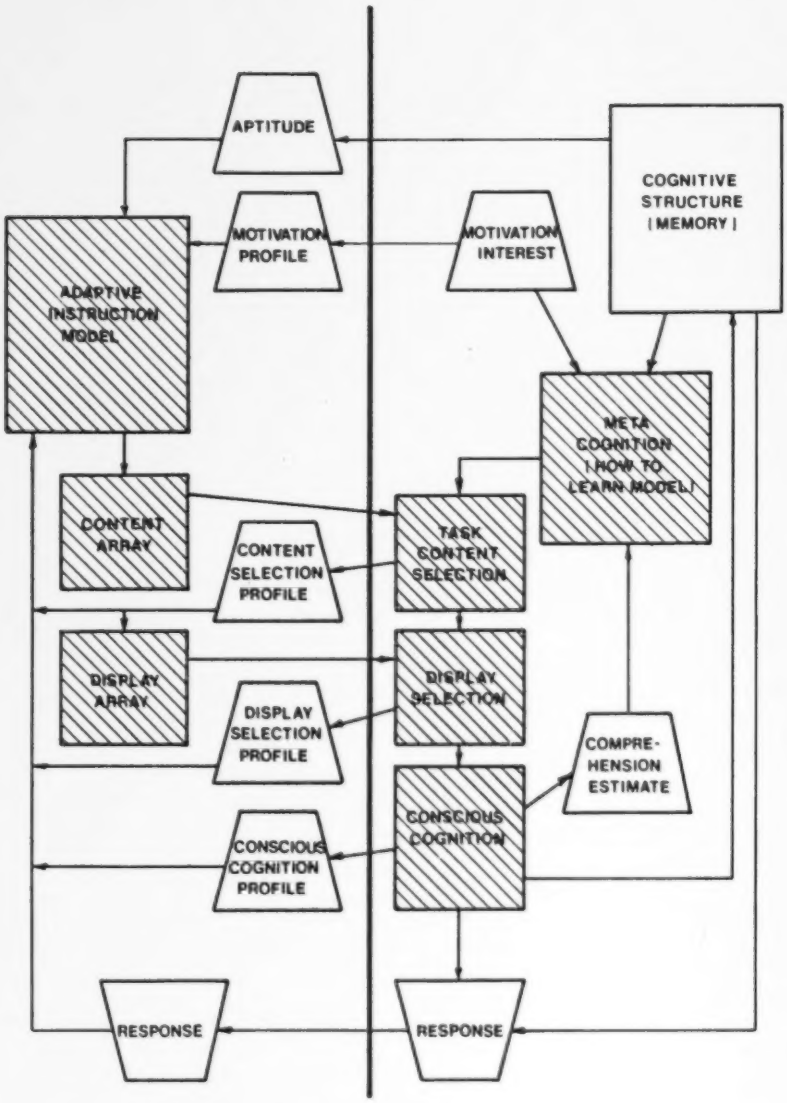

Figure 17-1. A model of a student/instructional system.

practice response. In a learner control system the student's record of which segments, lessons, and/or units are studied and in what order constitutes a content selection profile; a record of which displays were selected and in what order constitutes a display selection profile. These profiles indicate the unique path which each individual takes through the material and has in the past been referred to as the student's individualized instructional strategy.

It is also possible to query the student concerning the way s/he processed the information presented on a given display. Figure 17-1 refers to this level of processing as a **conscious cognition.** Conscious cognition refers to mental activities by which the student attempts to remember and integrate the information with that which has previously been learned. Often the first activity is to read the information presented (or in some cases to listen to an audio presentation). The student may then engage in one or more of a variety of possible cognitive activities including: **rehearsal,** repeating the information several times from memory; **repetition,** rereading or relistening to the material; **paraphrasing,** reformulating the information in the studnet's own words; **imaging,** trying to form a picture using the information; **encoding via a mnemonic,** trying to incorporate the information into a formal or idiosyncratic mnemonic system; **exemplifying,** trying to find in memory a previously

learned instance of the information; **covert practice**, trying to find a previously learned parallel to the information from some other subject area. If by an introspective interview we obtain a record of the processing attempted for each display then we have a conscious-cognition profile.

Meta-cognition refers to the student's personal "how to learn" model. Norman (1978) suggests that all students have some form of naive learning theory which they bring with them into a learning situation, but often their ideas are "quaint" and erroneous. In addition to processing the material as subject matter in its own right, it is postulated that students develop some model about how to learn within the individualized systems in which they find themselves. These models may be complete and systematic for some students yet incomplete or inconsistent for other students. Such models may be oriented toward content selection, display selection, or conscious cognitive processing. Such models are usually adaptive, enabling the student to adjust his content selection, display selection, or conscious cognition activities based upon internally perceived comprehension or upon external feedback. An example of part of such a model which may be used by a student is to feel that s/he should always look at a rule first, followed by one or more examples, followed by practice. An example of part of a conscious-cognition oriented model is the student who whenever presented a rule reads it three times and attempts to paraphrase it. As with conscious cognition, it is possible via introspective interview techniques to assess the meta-cognitive models being used by a student.

LEARNER CONTROL[2] AND INDIVIDUALIZED INSTRUCTION

There have been a large number of individualized instructional systems invented and explored. Almost everyone feels intuitively that individualized instruction is good and that learning should be better when instruction is somehow adapted to the unique abilities and aptitudes of the individual student. However, how does one compare one system with another? Are all individualized systems the same or are there significant differences in what constitutes the essential factors which are allowed to vary from individual to individual? Are all of these dimensions of individualization equally important or do some make a greater contribution to criterion performance than do others?

Individualized instruction means that aspects of the presentation are varied from one student to the next in an attempt to more adequately match the learning activities to the unique aptitudes and abilities of each student. Learner control means that adaptive instructional decisions are made by the student, as compared with system control, in which adaptive instructional decisions are made for the student. Individualized instruction always involves some form of learner control. In a previous section of this paper we suggested four levels of learner control. We would here suggest that an individualized instruction system differs with respect to which and how many of these levels of learner control are involved in the instructional situation. Two of these levels (display control and content control) are more easily manipulated by changes in the external instructional system than are the other two levels. Two of the levels (meta-cognition and conscious cognitive processing) are involved to some extent in almost any instructional situation. Not only is some form of learner contol involved in almost any instructional situation but also some level of individualization is also involved.

It was postulated in the first section of this paper that there are four potential levels of conscious processing over which the learner can exercise deliberate control: content selection, display selection, conscious cognition and meta-cognition (see Figure 17-1).

Individualized instruction and learner control involve the interaction of the functional components of an individualized instructional system with the four levels of conscious processing which have been identified. The degree of individualized instruction depends upon the parameter values which are assigned to the various functional components, that is, the content array, the display array and the adaptive model. The adaptive model used and the degree of selection and sequencing involved with the content and displays determine the external nature of individualized instruction. The degree of learner control depends upon the extent to which the learner can exercise each of the levels of conscious processing, i.e., content selection, display selection, conscious cognition and meta-cognition. Content selection and display selection are more directly controlled by the external environment, that is, by the type of adaptive model which is used and the delivery system by which the content array and display array are presented to the student. If the instructional system prescribes the sequence and selection for the content array, then the student has little opportunity to exercise content selection and thereby does not have learner control in the content selection process. Likewise, if the adaptive system prescribes the sequence and selection of the individual displays used to present a given content idea, then the student has little opportunity to exercise display selection, thereby being limited in the amount of learner control that can be exercised at this level of processing. However, in almost any instructional system it is difficult or impossible to completely control the degree of cognitive processing; therefore, a student in almost any instructional situation has control over the way to process the displays which are presented. Likewise, in every instructional situation the student uses some type of meta-cognition or "how to learn model." In a very real sense a student is adapting the instruction to his/her own needs no matter what the control or adaptation

involved in the external instructional system. However, the number of choices which the meta-cognitive model must control are more limited in some instructional situations than in others. For instance, if the content and display selection and sequencing are made by an external adaptive model for the student, his/her own meta-cognitive model does not need to prescribe rules for the selection of content or rules for the selection of displays. Therefore, the student's internal model is limited to the control of the cognitive processing which s/he would use for the externally sequenced and selected content and display presentations which will be presented. Nevertheless, the student can still exercise considerable control over how to process the information once it is presented.

Comparing Non-Individualized Systems

In Table 17-1 we have attempted to compare a number of instructional systems on the basis of the nature of the adaptive system involved and the degree of learner control involved. One use of the model specified in Figure 17-1 is that it enables us to describe more precisely the nature of the individualized instruction and resultant learner control in a variety of instructional systems.

Lecture. A lecture is a nonadaptive instructional system. A typical lecture is an expository presentation of a number of content ideas. In this situation the content array is selected and sequenced for the student; that is, the lecturer has previously decided which topics to treat first, which second, which topics will be included, and which topics will be excluded from the presentation. The individual displays within each topic are also fixed in terms of sequence and selection. Typically in a lecture these will consist of a series of generality presentations followed by one or more examples. Except in an unusual situation there would be little practice provided for the student within the context of the lecture itself.

Table 17-1. Comparison of instructional systems on basis of learner control involved.

	EXTERNAL FUNCTIONS			INTERNAL FUNCTIONS		
	ADAPTIVE	CONTENT ARRAY	DISPLAY ARRAY	CONTENT SELECTION	DISPLAY SELECTION	CONSCIOUS COGNITION
1. TYPICAL LECTURE	NO	SC	SC	O	O	PC
2. TYPICAL TEXT BOOK	NO	SC	SC	PC	PC	LC
3. STYLIZED WORKBOOK	NO	SC	SC	PC	LC	LC
INDIVIDUALIZED SYSTEMS						
4. ATI (LECTURE)	YES	SC	SC	O	O	PC
ATI (TEXT)		SC	SC	PC	PC	LC
5. TUTORIAL CAI	YES	SC	SC	O	O	LC
6. ADAPTIVE MODEL (ATKIMSOM)	YES	SC	SC	O	O	LC
LEARNER CONTROL SYSTEMS						
7. LEARNER CONTROL (ATKIMSOM)	YES	LC	SC	PC	O	LC
8. SOCRATIC MODEL (MAGER ETAL)	YES	LC	SC	LC	PC	PC
9. TICCIT	YES	LC	LC	LC	LC	LC

KEY:
SC = SYSTEM CONTROL
PC = PARTIAL CONTROL
LC = LEARNER CONTROL
O = NO LEARNER CONTROL

The total system might include homework which may involve practice, or perhaps additional expository presentations via textbooks and other situations. For our discussion let us consider only the lecture component of this particular instructional system. The various types of information which typically could drive an adaptive instructional model are not typically available in a lecture situation. That is, there are usually no profiles on motivation, content selection, display selection, or conscious cognition. Except for homework and tests there are very likely no responses, certainly not on a display-by-display or topic-by-topic basis.

In a lecture the student has little opportunity for content selection inasmuch as the content is presented in a fixed sequence. It is possible for the student to take notes or hold in mind particular topics and to some extent reorder them, but this is not typically done by most students. The student also has little display selection opportunity. A student can "turn off" to a given part of the presentation by failing to pay attention and thereby exercise some degree of selection but typically the student can control neither selection nor sequence of the individual displays. In a small class a student may interrupt by asking questions, which might enable the student to exercise some degree of display and sequence selection by requesting an example or asking for a clarification of a definition. However, in a large group lecture this control is not typically exercised.

However, the student does have considerable control over conscious cognition. One limitation here is the pacing involved in a lecture. A student may wish to pause and paraphrase a particular generality but because the next generality is already coming from the lips of the lecturer the student may not have sufficient time to engage in the type of conscious cognitive processing that s/he may desire. Students sometimes attempt to provide this opportunity by taking notes but oftentimes these attempts are inadequate. Therefore, the manipulation of conscious cognition is possible, but the types of cognitive activities in which the students can engage are somewhat limited by the pacing in the situation. The lecture provides a sort of control group for our discussion in which there is little opportunity for learner control and no adaptation to the student on the part of the instructional system.

Textbook. Let us consider a conventional textbook. A textbook usually does not involve any type of adaptive instruction. The content selection and sequence is fixed; the array of the displays is also fixed. A given chapter will present a generality, some examples, and may have some thought questions, but the arrangement of these is constant and the expectation is that most students will begin at the beginning of the chapter and study the material through to the end.

However, a textbook provides considerably more opportunity for learner control than does a lecture. A student can select those topics which s/he wishes to study and can, by reading various sections of the textbooks before orthers, order them as s/he wishes. The headings and other textual cues enable the student to reorder the material in ways that may be more consistent with previously acquired knowledge.

To some extent a student also has more display selection opportunity with a textbook. However, display selection is often limited because generalities and examples are often embedded in elaborative material. It often requires considerable search activity on the part of the student to isolate the generality or the example. It may be necessary for the student to study all of the material in order to find the generality, example, or some other display component. This makes the selection and sequencing of such displays more difficult. The potential does exist, however, for the student to scan the material in search of a generality or in search of an example without paying detailed attention to the remaining material, thereby making some degree of display selection and sequencing possible. There is a considerable degree of control over conscious cognition which can be exercised on the part of the student, much more so for the textbook than for the lecture inasmuch as the study is self-paced. A student can locate and isolate a generality for a particular topic and then can take the time to paraphrase it, to rehearse it, or to engage in whatever conscious cognition s/he feels may be appropriate for processing the information presented. On the instructional side, a textbook is equivalent to a lecture, but on the learner side there is considerably more learner control possible with a textbook than is possible with a lecture.

Stylized workbook. A stylized workbook is similar to a programmed instructional booklet but does not have the typical "swiss-cheese frames" which were familiar to us during the 1960's. Instead, each topic is clearly identified by objectives which indicate the tasks which the student will be expected to perform following study. Each section which relates to a given topic has a generality page which clearly states the definition, the procedure, or the relationship being taught. On the following page, in a separate paragraph, is additional elaboration of the generality including its relationship to previously learned information. On a clearly labeled separate page are a series of example. These examples relate directly to the generality. the examples are clearly separated so that the student can see that there are a number of examples. On the same page or on an adjacent page additional information is provided for each of these examples to focus attention upon critical attributes and to indicate to the student how these examples relate to the generality. On another separate page are a series of practice problems to which the student is requested to respond. The practice is followed by a feedback page which indicates not only the correct answer for the problems but also provides additional help information as to why the particular procedure or concept which was taught was used or classified as it was.

There is also assurance to the student that the test which will be used to evaluate his/her performance will correspond very closely with the practice items.

In Table 17-1, we have indicated that such a stylized workbook is not deliberately adaptive. The content selection and sequence are fixed in that the designers indicate the order of presentation for the materials. The display arrays are also fixed in that the same displays are available for all students. However, in this case the amount of information available probably exceeds that which any one student is expected to need. This format encourages learner control.

On the internal side we've indicated a partial control over content inasmuch as the typical pattern is for a student to follow the topics in the order in which they are given. However, because each section of the book deals with a separate topic the student can easily rearrange these topics, therefore enabling partial control. There is complete learner control as far as display selection is concerned. A stylized workbook of this type is designed to provide display control. The isolation of generalities, examples, and practice items and the various elaborations of them enable the student to choose only that material which is needed. directions in the workbook encourage the student to skip additional examples if s/he feels s/he understands the material, to skip the help pages if s/he feels the examples are clear by themselves, and to work only as many practice items as s/he feels are necessary in order to assure him/herself that s/he understands the material provided. There is also complete learner control of conscious cognition. As with a textbook, a student can spend as much time on a given display as s/he may wish, thereby rehearsing, paraphrasing or engaging in whatever other cognitive activities are necessary to understand the material.

Comparing Individualized Systems

Aptitude-Treatment Interaction. Consider an aptitude-treatment interaction in which there are at least two treatments: one presentation for high-ability students and one for low-ability students. The differentiation between students is based upon some aptitude which has been assessed before the instruction is presented. An ATI is a form of an adaptive instructional model. It consists of two fixed models rather than of a dynamic adaptive model, in that the instruction is not adapted on-line as the student engages in the instruction, but rather a decision is made on the basis of an aptitude profile input and the content is fixed in two separate arrays, one for the first aptitude level and the other for the other aptitude level. In some ATI situations the content is fixed and the display array is divided into two different arrays, one for the high-ability and one for the low-ability students.

The amount of internal learner control available to the student in an ATI situation is more dependent upon the delivery system used than it is upon the fact that it is ATI. In the situation which we have just described, if the materials are delivered via lecture then the student would be considerably limited as to the content selection and display selection and to some extent the conscious cognition in which s/he could engage. If, on the other hand, the treatments are administered via textbook or workbook, the student has the degree of content selection, display selection, and conscious cognition previously described for texts or workbooks. In an ATI individualized-instructional situation adaptation has been accomplished by grouping the students, but the degree of learner control depends upon the delivery system.

Tutorial CAI. Tutorial CAI is typically based upon an adaptive instructional model which is performance or response driven. Students are given practice problems as part of the presentation and the next display is determined from the student's response. In many such systems the content array is fixed; that is, the selection and sequence of topics is decided for the students rather than being adapted to different students. There are exceptions to this, but for our example let us consider a situation in which the content array is fixed. The adaptation takes place within the display array. The adaptive model used is a general model; that is, the adaptation is the same for all students, but the particular frame which a student might see depends upon the nature of the student response. In a typical branching-type program a student would be given one type of display if his response to the previous frame was correct, but a different type of display if his response was incorrect. The display may vary depending upon the nature of the incorrect response.

On the learner side of the situation, if the content is fixed the situation is similar to a lecture. If the student does not have content selection, a CAI situation is less flexible than a textbook. Display selection is also fixed, in that the student has no direct control over which display s/he will see next. Tutorial CAI is even more limited than a textbook in providing the opportunity for the student to override the system, since s/he can only look at one display at a time. If is often impossible to reorder or select the displays which s/he would like to look at.

Tutorial CAI, because it is self-paced, does enable the student to exercise almost unlimited control of conscious cognition. A student can study a given frame for as long as necessary, thereby enabling him/her to engage in a variety of conscious cognitive activities. As an adaptive system tutorial CAI enables more learner control than does a lecture but less than does a textbook. It differs from either, however, in that an attempt is made to select displays on a frame-by-frame basis which are appropriate for a given student.

Adaptive Model. Consider the adaptive model described by Atkinson (1972) to teach German vocabulary to a group of students in an

experimental situation. A list of 12 German words was projected in front of the room. A computer typewriter terminal typed the number of one of the words and the student was expected to type the English equivalent. The adaptive part of the system operated in such a way that the word to be tested was chosen by a computer program based upon two parameters: word difficulty and whether the word was permanent (that is, whether a student had really learned it or not), temporary (that is, partially learned but not completely learned), or unlearned. Permanency was determined by a student's response history and a mathematical model for calculating the degree to which the word was learned. The system was set up to optimize the number of permanently learned words that the student would have in her/his repertoire at the end of the experimental session and as demonstrated on a test in which he would be presented German words one at a time and expected to type the English word on the computer terminal. In a sense, this is an idiosyncratic adaptive model in that each student's response history is somewhat different, and therefore the word which a given student recieves next is different for each student, irrespective of his response to the immediate past item.

The selection and sequence of content in the content array was system controlled but was based upon an idiosyncratic adaptive model for each student. However, the display was exactly the same for all students and was therefore a fixed display. The display was a list of words, a number was typed and the student was required to type the correct word. Hence both the content and display arrays were system-controlled.

Internally, because of the system constraints, there is neither content nor display control. There is some partial control of conscious cognition. For example, the student can choose to rehearse the word several times, or s/he can choose to make a mnemonic out of it. The only limitation is the time involved and the limited display available to the student.

Comparing Learner Control Systems

Learner Control. By contrast, consider the learner control condition in the Atkinson (1972) experiment. In this case the situation was the same as described for the adaptive model, except that the student was able to choose, from the list of twelve words, which word s/he wished to respond to next, and to then type the response to that word, rather than having the system select the word. The comparison in Table 17-1 shows that the student has learner control of the content array instead of system control. The display array is still fixed; the student has no control of this.

Internally there is learner control as to content selection and sequence but there is no control as to display selection. There is about the same amount of partial control available for conscious cognition on the part of the student. The main difference between the two treatments was whether or not the computer selected the next word or the student selected the next word. It is interesting to note that this procedure represents a very limited type of learner control. The only controls available to the student were over which word to study next and some control over cognitive processing. All other functions were system-controlled.

Socratic Model. Consider the Socratic model as exemplified by the work of Mayer and McCann (1961). In this particular situation the student was given a list of objectives. S/he was then given access to a subject-matter expert tutor whom s/he could query concerning the objectives. The subject-matter expert essentially lectured to the student when the student chose an objective or when the tutor attempted to explain what the student wanted to know. The degree of Socratic dialogue involved here is unspecified in the description of the experiment, but presumably the subject-matter experts were instructed to provide only a minimum amount of information in the presentation and the student was to query additionally if s/he needed more understanding of the topic.

In this system the task is fixed; that is, the objectives are given to the student and the student is expected to master these objectives. The primary nature of the learner control was in the selection of content. The student could choose which objective s/he wished to work on next, could sequence the objectives in any order, and could choose to omit given objectives as s/he desired. We have indicated that the display array was fixed. To some extent this may be too strict, but it seems likely that the tutors in this particular situation gave a relatively fixed presentation when queried about a given objective. The presentations were probably very lecture-like in their nature; they probably presented the generality, and perhaps an example or a demonstration, for the student in the particular topic. The objectives were a comprehensive list at a high level of detail, each of them consisting primarily of a single topic.

On the internal side, there was learner control over content selection inasmuch as the student could choose which topic to study next and and could omit topics as s/he desired. We have indicated partial control over display selection. A student could ask the tutor for the additional examples, for a clarification of a generality, or for a different practice problem. The degree to which students engaged in this type of self-directed instruction is unclear from the description of the experiment but certainly is a possibility. For conscious cognition we have indicated partial rather than complete learner control inasmuch as the time involvement in the situation may have prevented certain types of processing. The student was probably under some constraint to respond quickly and not to spend too much time in processing the information given. This limits to some extent the type of processing in which s/he could engage.

TICCIT. Consider the TICCIT computer-assisted instrucion system (see Merrill, Schneider, and Fletcher, 1980). TICCIT is a complex learner-control system in which the student is presented displays on a television screen. The student can respond to the displays on a typical typewriter keyboard augmented on the right-hand side by a series of learner-control keys. The keys of primary concern in this description are the rule, example, practice, and help keys, by which the student can access various types of displays for a given segment or content topic. For each lesson, the student was shown a map which indicated all of the topics to be covered in a particular lesson. The student could select which topic s/he wished to study next and would then go to that topic, where s/he could select the types of displays which s/he would like to have presented to him/her. A student could also skip topics if s/he felt s/he understood them, and go directly to the test whenever s/he had worked on as many topics as s/he felt were necessary for his/her understanding. In this situation the student does have learner control over the content array. The student also has a relatively rich display array. S/he may decide what type of displays to look at, and how many. The student may skip displays, or may look at as many as necessary.

Under the degree of internal learner control we have indicated that there is complete learner control over the content selection, over the display selection, and over conscious cognition. Inasmuch as this is a self-paced system in which a given display stays on the screen for as long as the student desires, s/he may then have time to engage in any type of cognitive processing which is desired in studying the material. TICCIT is a relatively complete learner control system, both in terms of the external provision for control and in terms of the degree of internal learner control available to the student.

ADAPTIVE MODELS AND LEARNER CONTROL

An adaptive instructional model is one which allows for modification of the instructional strategy in response to inputs from the student. An instructional strategy can be conceptualized as a sequence of instructional displays. Thus an adaptive model is one which allows the kind and number of displays to vary from student to student and time to time during the instructional process.

Dimensions of an Adaptive Model

In an adaptive model the display selection procedures are based on certain assumptions about the relationship between student display performance or a student estimation-of-comprehension and the best display for a given student to receive next in a given instructional situation. There can be a wide variety of adaptive models which can vary on a number of different dimensions. Of concern for this paper are three such dimensions: model generality, locus of control, and driver.

Model Generality. Model generality refers to the idiosyncratic nature of the model. Does a given model apply to all students in a given instructional situation and under similar motivational conditions? Or does each student require an idiosyncratic model? Most tutorial systems assume a general adaptive model. Each student is presented the same display if a given practice item is missed. In contrast, an individualized model would present one type of display to student A but a different type of display to student B under the same display-performance conditions.

Locus of Control. Locus of control refers to who does the adapting, the learner or the system. In a learner-control model, the choice of the best display to be given next is made by the learner. In a system-control model, the choice of the best display to be given next is made for the learner. Tutorial systems are usually system-controlled. TICCIT (Merrill, Schneider, and Fletcher, 1980) is one example of a learner-controlled system.

Driver. The driver refers to that information which is used to make adaptational decisions. There are many different types of information which can be used to drive adaptive models. In this paper two sources of information are identified: student display performance and student estimation of comprehension. Student display performance includes correctness of response on practice frames and latency on displays. Student estimation of comprehension includes a student's prediction about test performance and expressions of readiness to take a test.

Presentation Displays

Display Types. We have previously suggested that an instructional strategy can be conceptualized as a series of displays (Merrill and Boutwell, 1973; Merrill and Wood, 1974; Merrill, Richards, Schmidt, and Wood, 1977; Merrill, Reigeluth, and Faust, 1979). This conceptualization allows the componentization of instruction and the systematic manipulation of instructional strategies. The primary presentation displays include, (a) **generalities,** such as the definition of a concept, the statement of a procedure, and the statement of a principle; (b) **examples,** such as instances of a concept and applications of a procedure or principle; (c) **generality practice,** which requires a student to recall or recognize a generality; and (d) **example practice,** which requires a student to classify an instance of a concept or to apply a procedure or principle to a given situation. These primary presentation displays include (e) **generality help,** which further defines components of the generality, represents the generality in another form, or illustrates the application of the generality to an instance; (f) **example help,** which uses attention-focusing devices to illustrate how the instance relates to

the generality; and (g) **practice-feedback help**, which uses attention-focusing devices to show the student how the problem was solved.

Instructional Value. The instructional value of a display refers to the contribution a given display makes to test performance. A nonadaptive model assumes that a given display which is part of a given strategy makes a similar contribution to the test performance of all students. An adaptive model assumes that the instructional value of a given display is a function not only of the strategy of which it is a part, but is also a function of the student's display performance and/or the student's estimation of comprehension. A general adaptive model assumes that for the same student response or comprehension level, the same display makes a similar contribution to the test performance for all students. An idiosyncratic adaptive model assumes that for the same level of student response or comprehension, the same display makes a different contribution to the performance of different students.

Variables Contributing to Student Performance

The instructional value of a given instructional display is potentially the function of four classes of variables: display context, student display performance, student estimation of comprehension, and motivational context.

Display Context. Display context refers to the relationships between displays which exist within a given instructional strategy, regardless of whether the strategy was determined by a fixed or adaptive model, whether the adaptive model was system or learner-controlled, whether the model was general of idiosyncratic, or whether the model is display-performance or comprehension-estimate driven. Such relationships can be assessed in a wide variety of ways. Some of the measures which seem relevant are illustrated, but not exhausted, by the following:

A simple measure of display-context is the **number** of displays. One measure is the total number of displays presented. Under a fixed strategy there would be no variance on this measure. Under various types of adaptive models there could be considerable variance in the number of displays presented. Number of displays can be subdivided into the number of the various kinds of displays, i.e., number of generalities, number of examples, number of practices, number of generality-helps, etc.

A second measure of display-context is the **relationship** of various kinds of displays. This measure includes various ratios of the number of one type of display to the number of another type. Some of the specific measures include: example to practice ratio, example to example-help ratio, practice to practice-feedback-help ratio, etc.

A third measure of display-context is the **sequence** of displays. One such measure assumes a fixed-sequence model such as generality, generality-help, example, example-help, and practice, practice-help. The actual sequence is compared with the fixed model and a deviation score is derived. Various measures could be derived by assuming different fixed-sequence models as the base.

Various other display-context measures could be derived. The above are sufficient to indicate the type of variable being considered.

Student Display Performance. Student-display performance refers to the various indicators of how the student is processing the information which is being presented via the displays. These measures are also independent of the models used to present the instruction, but may be affected by the model being used. Some of the indicators of student display performance which seem relevant are illustrated by, but not exhausted by, the following two measures:

Instructional Time represents one display-performance measure. At the most general level the total-time-to-learn is one such measure, and it can be partitioned in various ways such as time on various types of displays: rule-time, example-time, practice-time, etc. Various time-per-type-of-frame ratios may also yield useful performance information. Such measures might include generality-time to example-time ratio, generality-time to practice-time ratio, example-time to practice-time ratio, etc. These time ratios could be based on total time per type of display or on a time-per-display basis.

Correctness of Response on practice frames, which has been the most common driver for tutorial adaptive models, is perhaps the most obvious display performance measure. there are several specific measures which could be used. Percent-correct-practice is perhaps the most obvious. Other measures include practice-missed to practice-feedback-help ratio, Practice-correct to practice-feedback-help ratio, recency scores, etc.

Student Estimates of Comprehension (EOC). Student estimates of comprehension (EOC) refers to the student's estimation of how well s/he understands the material which is being presented. There are various ways to assess this information. At present the following procedure seems most appropriate.

Each display could contain a 7 or 9 point scale. The student could be asked to respond to this question following each display: "If you were to be tested at this point in the lesson how well do you think you would do? At one end of the scale the descriptor would read "none correct;" at the other end of the scale the descriptor would read "all correct." After the first few frames, after the learner has become familiar with this assessment, the question itself could be ommitted and only the rating scale included in each display.

Following each display the student could also be asked to indicate whether or not s/he feels ready to take this test. Under some conditions this could allow the student to take the test. Under other conditions this would merely serve as an

indication of readiness, with the model being employed determining whether or not the student is allowed to take the test at that point in the instruction in some other way.

Motivational Context. The contribution of each of the previous classes of variables to student test performance may likely be different under different motivational states. For purposes of this paper two motivational dimensions are proposed: level-of-aspiration (LA) and momentary-need-for efficiency (MNE).

Level-of-aspiration (LA) refers to the desire on the part of the student to get as many correct as possible. In real-world settings different students often have long-term differences in level of aspiration as a result of their success in their interaction with instructional situations. In experimental situations short-term level-of-aspirations could be manipulated by contingency management.

Momentary-need-for-efficiency (MNE) refers to a student's desire to complete the instructional task as soon as possible or his/her willingness to stay for a prolonged period of time. In real-world settings different external contingencies affect the momentary-need-for-efficiency for each of us. In research investigations momentary-need-for-efficiency could be manipulated by contingency management.

Examples of Adaptive Models

A Performance-driven Remediation Model. The driver of this model is a correct or incorrect response on practice items. The model is remediation based. Depending upon the instructional context, the model could be either general-adaptive or idiosyncratic. The model could be either system-controlled or learner-controlled. The basic form of the model is illustrated in Figure 17-2. The model operates as follows: a criterion of k or k-in-a-row correct practice items is established. The student is presented an objective, including a sample test item. The student is next presented a practice item. If the student responds correctly to the practice item s/he is presented another practice item until s/he has met the criterion. If the response is incorrect s/he is presented some form of remediation and then presented another practice item until the criterion is met. The remediation subroutine could take several forms. One possibility would be as follows: first error, branch to practice-feedback-help display; second error, branch to example; third error, branch to example with example help; fourth error, branch to generality; fifth error, branch to generality-with-help. This branching structure would be reset after every correct response. The rationale for this model is to provide a lean instructional program; generality and example frames are provided only as remedial information when the student can't figure out how to solve a problem. Data from the TICCIT system (Bennion, 1978) indicates that many students under learner control seem to adopt a remediation model in their choice of displays.

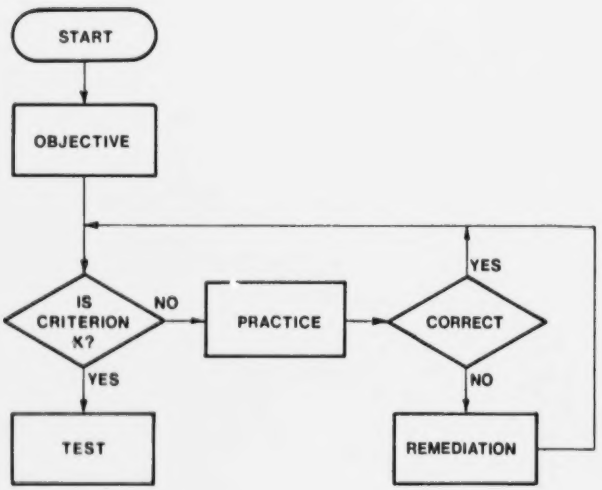

Figure 17-2. Performance-Driven remediation model.

EOC Driven Generality-Example-Practice Model. The driver of this model is the student's estimate of his/her understanding of the content being presented. Under system-control the driving mechanism might be as follows: the student would be asked to estimate his/her performance if a test were to be given immediately following the current frame (i.e., provide EOC). The model operates as follows: if there is an increase in EOC since the last display, shift up; if there is no change in confidence, stay; if there is a decrease in confidence, shift back. The basic form of the model is shown in Figure 17-3. The student is presented an objective and asked to give EOC. If EOC increases, the student is shown an example. If there is no increase, the student is shown the generality-help; and so forth as illustrated by the flow chart. We designed an "advisor" for the TICCIT system based on a variation of this model. In the TICCIT system the advisor provided a recommended display, but did not compel the student to be presented this display. This particular version of the advisor has not been completely implemented on the current operating TICCIT systems.

An EOC-Driven Model with a Performance Criterion. This Model is a combination of the previously described models. In this model the driver is EOC, conditional on having reached some specified criterion of correct practice. The basic form of the model is illustrated in Figure 17-4. The operation of this model is similar to that described for the EOC model in Figure 17-3.

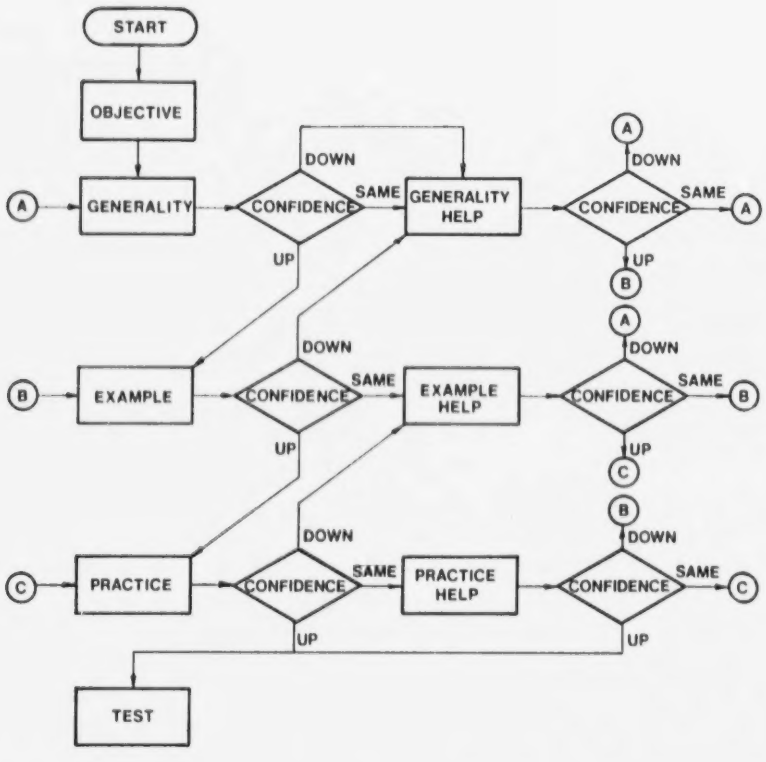

Figure 17-3. Confidence-Driven generality—example—practice model.

What Level of Adaptive Model is Necessary?

Three general levels of instructional models have been described. The first level includes non-adaptive models in which the instruction is the same for all students in a given instructional situation regardless of their display performance or of their estimation-of-confidence. The second level consists of a general adaptive model which adjusts to each student based upon the student's display performance or estimation-of-confidence, but the nature of the adaptation is the same for all students. The third level includes idiosyncratic adaptive models which not only adapt to each student based upon display performance or estimation-of-confidence, but the way in which they adapt differs for each student depending upon other individual-difference factors. For each of these levels of adaptation a wide variety of specific models can be identified depending upon the specific displays involved, upon the nature of the driver involved, and upon the locus of control.

Are Adaptive Models Necessary? If it can be demonstrated that test performance is determined primarily by display-context variables in that a certain combination of displays seem to promote maximum performance for all students under a given motivational condition, then it does not seem necessary to construct elaborate adaptive models. All that is necessary is to use strategies which implement the observed display-context and all students will demonstrate maximum performance. If, on the other hand, it can be demonstrated that test performance is contingent upon student display-performance or student estimation-of-comprehension in addition to display-context THEN adaptive models are necessary for optimal test performance.

Are Idiosyncratic Adaptive Models Necessary? If idiosyncratic models are not necessary THEN a system-controlled model is practical. a learner controlled model may still be desirable for other reasons (such as for learning how to learn or helping the student to become system-independent) but it cannot be argued that an idiosyncratic adaptive model is a necessary condition for learning the material in the optimal way. If, on the other hand, idiosyncratic models are necessary, THEN a learner-controlled model is more practical. This argument is elaborated as

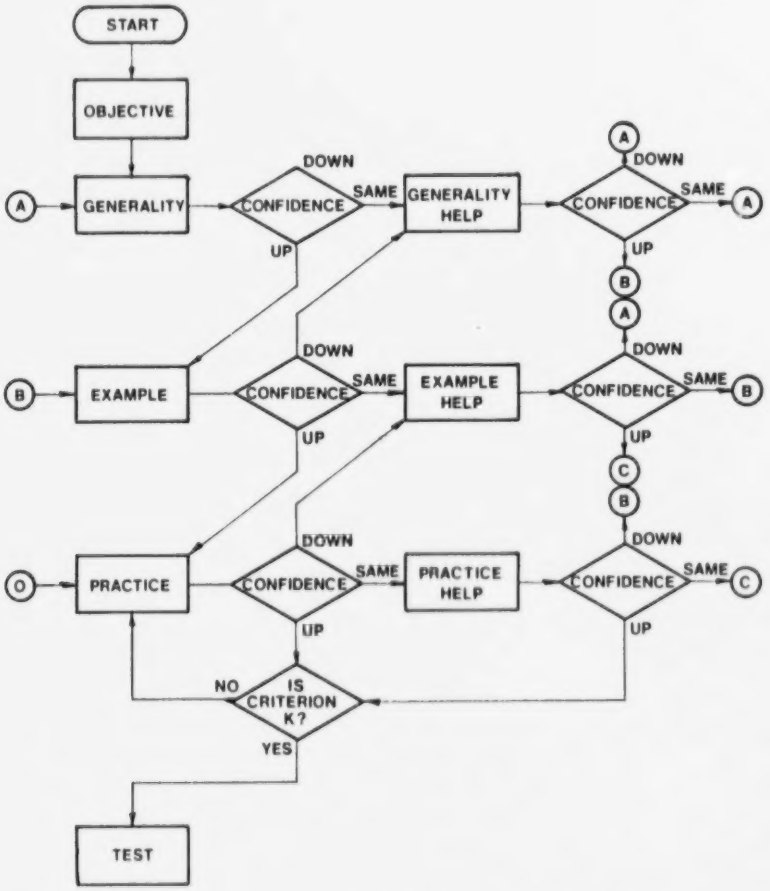

Figure 17-4. Confidence-Driven model with performance criterion.

follows. If every student requires a unique combination of displays in order to optimize his/her acquisition of a given lesson, then for system-controlled models the development costs begin to become unreasonable. An adaptive system-controlled model requires preassessment of every student to determine the appropriate idiosyncratic adaptive model. A very complex general program would need to be developed to allow programming the computer to implement this idiosyncratic model, or a separate, unique program would have to be prepared for each student. To be practical, a student would need to maintain the same idiosyncratic strategy over time. If the adaptive model was not only idiosyncratic amoung students but also idiosyncratic for the same student at different times and for different subject-matter contents, then preassessment would be at best temporary and the programming problem considerably compounded.

On the other hand, if a student can exercise learner-control then a general purpose program can allow the student to adapt the strategy to his/her own idiosyncratic needs, even if these needs change over time and occasions.

If research demonstrates that learner-controlled adaptive models are desirable then some additional questions need to be considered. If the necessary idiosyncratic adaptive models are driven by display performance then one needs to know 1) What information is necessary for a student to monitor his/her display-performance? 2) Can s/he monitor his/her display performance, given this information? 3) If not, can s/he be taught to monitor his/her display performance? 4) Can the student make the appropriate display choices, given that s/he can monitor display-performance? and 5) If not, can the student be taught to make the appropriate display choices?

If the necessary idiosyncratic adaptive models are driven by estimation-of-comprehension, then one needs to know 1) What information is

necessary for a student to monitor his/her level-of-comprehension? 2) Can s/he monitor his/her comprehension, given this information? 3) If not, can s/he be taught to monitor his/her comprehension? 4) Can the student make the appropriate display-choices, given that s/he can monitor comprehension or be taught to monitor comprehension? and 5) If not, can the student be taught to make the appropriate display choices?

RESEARCH ON LEARNER CONTROL

Content Control

O'Neal (1977) reviewed a number of studies which investigated the student's ability to sequence units or modules of instruction within a course. (Allen and McDonald, note 1; Grubb, note 2; Judd, Bunderson, and Bessent, 1970; Thomas, 1971; Beard, Lorton, Searle, and Atkinson, 1973; Issing and Eckert, 1973; McCann, Lahey and Hurlock, 1973; Seidel, 1973; Mayer, 1976). Most of these studies support the finding that students who are allowed to sequence units or modules do at least as well as students who are presented fixed sequences, and when students are allowed to skip of skim modules which they feel that they already understand, their learning time shows considerably more efficiency.

Control Of Pace

O'Neal (1977) also cited a number of studies which have investigated pacing. The results are somewhat mixed, generally showing that self-paced learners do no worse than externally-paced learners; and that given appropriate training and some guidance as to adequate progress-against-time, self-paced learners may be considerably more efficient than externally-paced students. There is also some evidence that slow learners do better, given externally slow-paced instruction, rather than being allowed to self-pace the instruction.

Display Control

Our own work involved a series of studies investigating learner-control of presentation displays within a given lesson (NSF Project SED-76-01650). Most of the investigations conducted during this project addressed the following general hypothesis:

> If a learner is provided carefully defined strategy options and is allowed to determine the instructional display s/he wants next, his/her achievement, efficiency, and attitudes toward the instructional situation will be superior to those obtained in a situation in which the next display is prescribed.

The general conclusion which seems warranted by the research conducted is that this hypothesis was not supported in the unqualified way in which it is stated. On the other hand, none of the data collected indicated that allowing the student display-selection on a frame-by-frame basis resulted in a decrement in effectiveness, efficiency, or appeal. The following paragraphs will indicate some of the more specific outcomes which were supported, and some of the findings which have led us to modify the hypothesis and have suggested further research.

Primary Presentation Forms. The research investigations of this project are based upon the assumption that all instructional strategies are composed of certain fundamental types of displays. Most cognitive subject-matter can be represented either by a specific object, event, or symbol, or by representations of such specific occurrences via pictures, diagrams, or other mediated presentations, all called instances; or by a statement of the general case, called a generality. Generalities are statements of definition (for concepts), steps (for procedures), or relationships (for principles) which can be applied to a variety of specific situations.

Each of these two levels of representation (generality and instance) can be presented to the student in two different modes: expository or telling, and inquisitory or asking. Combining generalities and instances with telling and asking results in four primary presentation forms: telling-a-generality, which is usually called "rule"; telling-an-example, which is usually called "example"; asking the student to identify an instance, execute a procedure, or explain a particular event, which is called instance-practice or merely "practice"; and asking the student to remember a generality, which is often not included as a separate function in much of the work which we have done. In addition to the primary presentation forms, there are various forms of elaboration associated with each display type which are called "help" in the work which is reported. These primary presentation forms are what is meant by "clearly-defined strategy options." The TICCIT system, which was used for much of the reported research, makes these strategy options available by providing "rule," "example," "practice," and "help" buttons to the student.

As a preliminary basis for our work on learner-control of strategy options or display-control, it was thought desirable to investigate two hypotheses related to our previous work, which has come to be called component-display theory. These hypotheses are as follows:

1. A segment of instruction should include all three of the primary-presentation forms: rule, example, and practice. (A segment is defined as that instruction necessary to teach a given concept, procedure, or principle.)
2. The primary-presentation forms for a given segment of instruc-

tion (not under learner-control) should be sequenced in some variation of rule-example-practice.

Four of the studies we conducted investigated one or both of these hypotheses (Reigeluth and Merrill, 1977a; Reigeluth and Merrill, 1977b; Spiller, Rogers, and Merrill, 1978; and Coleman and Merrill, 1979). The results of the various studies were not completely consistent; however, the findings tend to show that test performance is higher when all three primary-presentation forms are present. Considered separately, practice tends to make the greatest contribution to test performance. When sequence was significant, performance is superior when a rule-example-practice order is followed. These studies do provide some support for these primary-presentation form hypotheses.

Isolation. In most text presentations the primary-presentation forms are buried in prose, making it difficult for the student to omit a particualr display or to reorder the displays. If the individual displays are physically separated from one another and clearly identified, then the student is better able to exercise learner-control of display-selection. The isolation of primary-presentation forms in text is similar to providing the student wih rule, example, practice, and help buttons on the computer system. Another hypothesis from component-display theory which we felt would be desirable to investigate in conjunction with the proposed research is the following:

3. The primary presentation forms for a given segment should be identified and isolated in such a way that a student can easily locate, skip, or review a given display.

Three studies investigated this hypothesis (Wilcox, McLachlan, and Merrill, 1977; Wilcox, Richards, and Merrill, 1978; and Wilcox, Richards, Hindmarsh, and Merrill, 1978). The results of these studies provide some support for this isolation hypothesis. There was considerable improvement in efficiency when the generalities and instances were isolated, summarized, and identified. In one of the studies the text performance was also significantly increased for the isolation groups.

Number of Displays. Perhaps the fundamental learner control variable is whether a student can determine when enough displays have been studied to optimize test performance. The following hypothesis was investigated as part of this project:

4. Students are capable of selecting the optimum number of instances (examples and practice) they need in order to master the lesson material.

O'Neal (1977) cited several studies which investigated control of amount of practice. (Dean, note 7; Beard, Lorton, Searle and Atkinson 1973; Fisher, Blackwell, Garcia, and Green, note 8; Newkirk, 1973; Slough, Ellis, and Lahey, 1972; Lahey, Crawford, and Hurlock, 1975). In most cases it was demonstrated that students were able to judge when they had practiced enough to reach an acceptable level of mastery of the content being presented.

We conducted five studies which investigated aspects of this hypothesis (Walker, Axtell, Warner, and Merrill, 1977; Walker, Axtell, Fletcher, and Merrill, 1977; Walker and Merrill, 1978; Wilcox, Richards, Christiansen, Rosenvall, and Merrill, 1978; and Strickland, Wilcox, and Merrill, 1978). Students studying logarithms on the TICCIT system were divided into groups of students who could select the number of example-and practice-displays they wished to study, and groups of students who were required to study only a few or many instances. Students who studied only a few instances scored significantly poorer on the test than did students who decided how many instances to study. Students who studied many instances did not score any better than those who selected their own number. A group of students who were required to study as many instances as the mean of the group who selected their own number of instances did as well as the learner-control group. Other combinations and treatments were explored, and the conclusion was confirmed that students can decide how many example-and practice-items they require for mastery. An important ad hoc observation was that there is considerable variance within the learner-control group. Some students choose a considerable number while others select only a few. There is also considerable vairance in the ratio of example-to-practice items - some choose many examples and only a few practice items while others choose only a few examples and many practice items. The data provides considerable support for the number-of-instances hypothesis.

Display Sequence. A second obvious display-control hypothesis is concerned with the order or sequence in which the student studies the various kinds of instructional displays. It seems logical that the student should be able to determine what kind of information s/he needs next. For one student the best display to view next may be the rule display. The following hypothesis was investigated as part of the project:

5. Students who are allowed to select the best display to view next will perform more efficiently and effectively than will students for whom the next display is prescribed by the system or follows in a fixed sequence.

Five studies investigated aspects of this hypothesis (Walker, Axtell, Warner, and Merrill, 1977; Walker, Axtell, Fletcher, and Merrill, 1977; Walker and Merrill, 1978; and Wilcox, Richards, Christiansen, Rosenvall, and Merrill, 1978; and Strickland, Wilcox and Merrill, 1978). Students learning logarithms on TICCIT were used as sub-

jects. One group was allowed to look at rule, example and practice displays in any order they wished; another group saw rule, example and practice displays in this (rule, example, practice) order. There were no group differences. However, there was considerable variance as to sequence in the learner-control group.

In an attempt to determine if certain patterns of displays were associated with good performance while others were associated with poor performance, we conducted a series of regression analyses using a considerable number of display variables. Some of this work is reported in Strickland, Wilcox and Merrill (1978); however, we ran many more such correlations than have been reported. Because none of the results were significant we did not report all of these analyses. Some of the variables used included: total number of displays used, number of examples, number of practice, number of correctly-tried practice, ratio of example-to-practice items, ratio of practice tried-to-practice correct, total time on task, time on rule-frames, time on example-frames, time on practice frames, various time/performance ratios, and others. The only variable we tried which had a significant correlation with performance was an estimate-of-effort which was provided by the students on a post-experiment questionaire.

Do these results mean that there are no general display variables which contribute to performance? We have considerable strategy variance and no correlations. Perhaps students really are trying to adapt the displays to their own needs. Suppose some students are successful in this attempt while others really select displays in a way which is detrimental to their performance. The net result would be no group differences. Maybe students who use an adequate internal adaptive model really do optimize their performance while those who use an inadequate internal adaptive model cause a decrement in their performance. The data we have does not allow us to make this separation of students. We were unable to resolve this dilemma during the duration of the project. Our data do not support the sequence hypothesis.

Help. Primary-presentation forms can be elaborated to include information designed to facilitate the student's comprehension of the subject matter presented in a rule, example or practice display. These elaborations are called rule-help, example-help, and practice-help. The following hypothesis was also investigated as part of the project:

> 6. Students who have learner control of rule-help, example-help, and practice-help will perform more efficiently than students who have no help or students who are always presented help.

Three studies investigated this hypothesis (Axtell and Merrill, 1978; Axtell, Callahan, Welsh and Merrill, 1978; and Hetzel and Merrill, 1978.) When students are given the choice of selecting help-displays* we found that students who had learner-control over generality-help performed more efficiently and effectively than other groups. However, students who had learner-control over example-and practice-help performed significantly less efficiently and effectively than did other groups. When students do not have practice help available they tend to work practice items over and over until they get them correct. When they can use practice-help they do not work the problems again. Apparently in this situation practice-help gave a false sense of understanding, thus the students in this treatment are less-well prepared for the test. On the other hand, having only generality-help seems to assist the student in preparing for the subsequent practice and test items, thus better preparing students in this group for the test. This suggests that the ability to solve problems utilizing a concept is not equivalent in all cases to a complete understanding of that concept.

Strategy Training. Perhaps one of the problems with the foregoing studies is that students are unfamiliar with the opportunity to make moment-by-moment display-choices during instruction. If students are provided some type of training in how to use learner-control their performance should be better than if they are left on their own. While we did conduct some studies related to this question, we feel that we have only scratched the surface of the potential. The following hypothesis was tested as part of the project.

> 7. Students who are provided directions in how to use display-control will perform better than will students who do not receive such instruction.

Three studies addressed this hypothesis (McLachlan, Schmidt and Merrill, 1977; Callahan, Richards and Merrill, 1979; and Hetzel and Merrill, 1978). In each case some form of written directions about how to use learner-control was given to the students. None of the studies supported the hypothesis. We are not convinced that the hypothesis is incorrect, only that the directions we used were inadequate to change a life-long habit. Students are not accustomed to having learner-control over individual displays, and tend to settle for some rather simple adaptive method of display selection rather than carefully weighing the need for the next display. A study by Strickland, Fletcher, and Merrill (1978) directed students to

*A Generality-help display is a display which represents the generality from a previously-presented generality-display, but presents it in a new form or through instances which illustrate or exemplify it.

An example-help display is a display which utilizes attention-focusing devices to show how the instance relates to the generality.

A practice-help display is a display which uses attention-focusing devices to show how a problem was worked.

maximize learner-control by selecting only as many frames as absolutely necessary, and to examine a given frame for only as long as necessary. Again there were no significant performance differences, although there tended to be some display-selection differences. In all cases it was concluded that the directions themselves may not have been adequate or that they may have been too complex. Hence, as far as the investigators are concerned, this question remains unresolved.

We did begin to investigate one other aspect of strategy-training which seemed to have more promise. the following hypothesis was also investigated as part of the project:

> 8. Students who are provided directions for conscious cognitive processing of the information presented will perform better than will students who are left to their own internal processing strategies.

Two studies investigated this hypothesis in part (Wilcox, Richards, Hindmarsh and Merrill, 1978; and Callahan and Merrill, 1979). In both cases students were directed in specific ways to think about the material they were being presented. In both studies those students who received directions about how to process the information scored higher on the posttest than did students who did not receive this direction. The Callahan and Merrill study also demonstrated that different directions are appropriate for different outcome measures. We feel that this work has important implications for the future, and may be the most important finding of the entire project.

Rewards. We have already indicated that one of the problems in learner-control research is student motivation. If a student is poorly motivated s/he may use the learner control available to get out of the experimental situation regardless of his/her performance. On the other hand, other conscientious students look at every available display in an attempt to do well and not "ruin the experiment," and so omit no displays. This problem was solved to some extent by selecting samples of students from ongoing classes in which the subject-matter of the experiment in which they were involved was part of their class-work. We also studied the problem directly to a limited extent. The following hypothesis was addressed by this project:

> 9. Students who are provided some external incentive will use learner-control in order to be more efficient than will students not provided with such an incentive.

Only one study addressed this hypothesis directly (Callahan, Richards, and Merrill, 1979). The extrinsic reward was a free ticket to a downtown movie (worth $4.00). Students were directed to be as efficient as possible by selecting as few displays and taking as little time per display as possible while still scoring at the 80% level. The directions were not sufficient to produce differences in performance which could be attributed to the extrinsic reward. This one study failed to confirm the hypothesis. However, the investigators feel that if the reward were of more value, the directions more explicit and the contingencies more clear-cut, that there would be differences introduced as a result of motivational incentives. More work needs to be done in this area.

Aptitude-Treatment Interactions. While the principal investigator has suggested that learner-control may be an alternative to aptitude-treatment interactions (Merrill, 1975) it is nevertheless possible that the ability to profit from the use of learner-control may be itself a treatment that interacts with student abilities. Two studies investigated ATI questions (Wilcox, Wilson, Richards and Merrill, 1978; and Norton, Wilcox, Fletcher and Merrill, 1978). The Wilcox, et al., (1978) study measured various aptitudes which were thought to be candidates for enabling a student to profit from the use of learner control over display-selection. The pilot study showed an interaction with locus-of-control, but a more elaborate study failed to replicate this finding. None of the aptitudes measured provided the ATI's we expected. One of the problems with this study was the small sample size. ATI correlational studies require a much larger sample size than do typical experimental studies in which interactions are not predicted.

The second study (Norton, et al, 1978) examined visual and verbal ability. Students were allowed to determine which, a visual or a verbal presentation of the subject-matter material, they wished to see. The expectation was that those who were visual would prefer visual material and do better. The hypothesis was not supported. Wilcox (1979) reviewed 14 studies by other investigators which showed that certain abilities tended to interact with the student's ability to use learner-control. Hence this issue is also not resolved but requires more investigation.

NEW DIRECTIONS

As a result of work on this project, we have been led to think about learner-control in some new ways. First, we would suggest that there are several kinds of learner-control: content-control, display-control, and control of conscious-cognitive processing. Second, we postulate that every student has some type of internal "how to learn" model which directs his/her use of each of these types of control. In view of this conceptualization we believe that every instructional situation has some amount of learner-control involved. In our opinion, helping students to develop internal adaptive models which direct their use of appropriate internal processsing is the most promising area for further exploration.

The model of internal and external learner-control which is presented enables us to con-

ceptualize meaningful research in several directions. One such direction is a way to compare individualized instructional systems more adequately than has been possible in the past. as described above, it makes possible the explication of conscious-cognitive processing and its role in adaptive instruction. It also clearly separates internal from external adaptive models of instruction and clarifies the interaction between the two.

In our opinion the challenge for the future is not whether or not we should arrange instructional situations to facilitate display or content selection, but rather that we should seek to identify the nature of the learner-control in every instructional situation. We need to know more about the types of conscious-cognitive control which may be appropriate for different kinds of outcomes and for different kinds of displays. We need to investigate ways to help students to learn to use more appropriate processing in these situations. And we need to explore the possibility that the adaptive model and conscious-cognitive processing which is appropriate for one student may be different from that which is appropriate for another student. In our opinion, the challenge is not to discover whether or not learner-control, but rather to help every student to maximize the use of the learner-control which is already available.

SUMMARY

A number of levels of learner-control have been defined in this paper. Content-control exists when a student can select and sequence segments, lessons, or units of instruction within a course. Content-control sometimes appears in a form which permits the student to omit content components which the student feels s/he already knows. Content-control is limited by the delivery system but it is always possible, even in conventional situations which involve textbooks and other forms of individual study.

Display (strategy) control exists when a student can select and sequence individual presentation displays--rule, example, practice--or elaborations of such displays--rule-help, example-help, practice-help, and feedback. Such control is facilitated by systems especially created for isolating and identifying these individual presentation forms. Display-control is not limited to computer-based systems, but can easily be implemented through textbooks, workbooks, and other individualized media by isolating and identifying the individual presentation-displays and by encouraging students to select only those displays which they feel they need. Students can also learn to exercise display control in conventional materials such as texts and workbooks, given a self-paced environment and appropriate instructions.

Conscious-cognitive control always exists in every instructional situation. The student must always choose what to do to encode the material presented. There is little data as to the variety or effectiveness of the techniques used by students to process the information they are presented. A number of questions suggest themselves: Through the choice of an appropriate processing strategy, can a student compensate for a less-than-adequate display presentation? Do students use the most effective processing strategies available? Can they be taught more effective processing?

Every instructional situation always involves for each learner an adaptive individualized learner-controlled model of learning. In externally-adaptive situations this model guides all three of the other levels of learner-control: content-selection, display-selection, and cognitive-strategy-selection. In situations where content and displays are prescribed, the learner's idiosyncratic model still provides rules for adapting the instruction for the learner via the appropriate use of processing strategies. A number of questions suggest themselves: Do students typically have well-developed conscious adaptive models, or are they somewhat haphazard, inconsistent, and frequently maladaptive? Can students be taught more effective adaptive models which will increase their performance in a variety of learning situations? Can students learn to be systematic in the application of such models? Are such models idiosyncratic to the individual or do general models exist which are facilitative to a variety of individual students?

Finally, to investigate learner-control vs no learner-control is not a sufficiently constrained question. One must at least specify the level of control one is investigating. All instruction involves some learner-control; the challenge is not whether or not learner-control should be made available, but rather how to maximize the student's ability to use the learner-control available. Given a system which allows content-selection and display-selection, the important question is how to help the student maximize his/her choices and match them with appropriate cognitive processing activities in order to maximize performance. Given a more restrictive instructional environment which prescribes content sequence and display-selection for the student, the important question is how to help the student select those cognitive processing activities which will maximize performance in this type of situation. Ultimately, the student who has the most choices available will be best able to maximize the effectiveness and efficiency of a given learning situation.

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FOOTNOTES

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